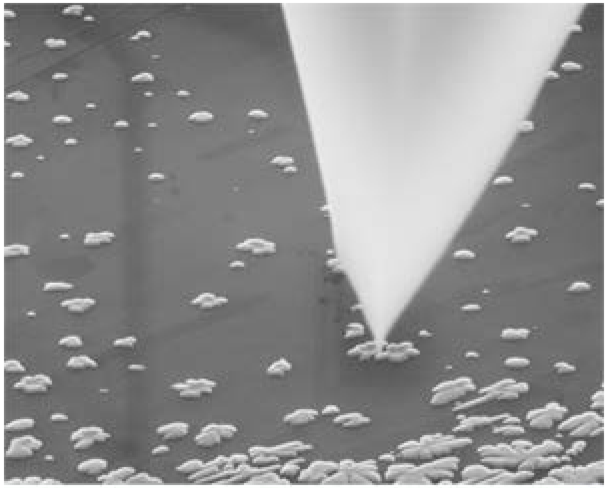
Dragging Nanoparticles Reveals Extra-low Friction

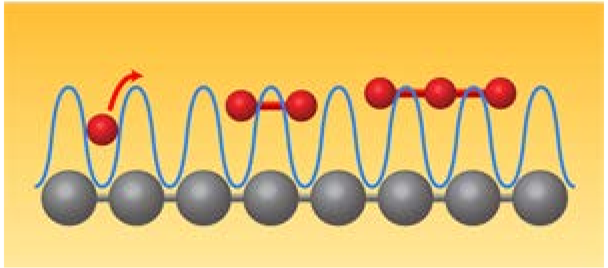
What is Friction on the atomic scale ?

If you slide a block across the floor, the floor's roughness presents tiny peaks that obstruct the downward peaks from the block's lower surface. In order to move, the block must "climb" over the floor peaks by rising up ever so slightly, which translates into lost energy, or friction. A similar process is expected to occur at the microscopic level when two surfaces contact each other. Here, the "roughness" is due to the atoms on the bottom surface that essentially obstruct the atoms on the top surface by presenting a potential energy barrier, or peak, they must climb over to move forward. If the two surfaces have the same atomic structure, then they can lock into each other periodically. In this case, the friction is proportional to the area.

How do they do this experiment ?

The nanoparticles were made of either amorphous antimony (which shouldn't match the atomic spacing for any crystalline surface) or crystalline gold. By varying the growth time, the researchers produced nanoparticles with contact areas from 2000 to 200,000 square nanometers, as determined with an atomic force microscope (AFM). After imaging, the researchers selected a nanoparticle, pressed it with the ultrafine point (called the tip) of the AFM probe and then dragged it along the surface at a constant speed of 1 micrometer per second. The team determined the friction force from the bending of the AFM cantilever connected to the top of the tip.





This picture shows the friction under the microscope. **This scanning electron microscope image shows the atomic force microscopy tip as it prepares to push an antimony nanoparticle along the graphite surface (top). The larger a nanoparticle, the larger the mismatch of its atoms with the potential energy valleys of the bottom surface. This mismatch results in lower friction than would otherwise be expected.**

More detail on http://physics.aps.org/articles/v6/130

Results

The experiments demonstrate the breakdown of one of the basic laws of friction at the atomic scale, where more slippery conditions prevail. This results may help link the theory of atomic interactions with that of large scale friction forces and may also boost development of low friction materials of small devices

Application to single atom

The researchers also showed that their results could extend to single atoms. They converted the force-area relationship into a relationship between friction and the number of atoms. From this, they derived the "friction" for a single atom and found it was consistent with the surface "stickiness" that others have measured from studying the diffusion of single atoms on a graphite surface.